H I L G A R D I A

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LEAF ANALYSES OF DIFFERENTIALLY COVERCROPPED DECIDUOUS FRUIT TREES[1]

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INTRODUCTION

IN THE COURSE of a covercrop experiment started at the California Agricultural Experiment Station at Davis, California, in 1922, analyses of various parts of trees were made from time to time. These analyses were done primarily to determine whether any of the practices included in the experiment had caused changes in the composition of tissues. Nitrogen was the element most commonly determined. Soil analyses (Proebsting, 1929; 1930; 1933) which seemed to show adequate nutrient levels did not indicate differences between plots that would have suggested marked differences in potassium or phosphorous contents of the tissues.

Various plant parts were sampled from time to time, but for some years sampling was restricted to basal leaves of shoots of moderate vigor, at a height which could be reached from the ground. Basal leaves, in contrast to spur leaves, were available on trees of all species and ages. They seemed less affected by size of crop than did spur leaves. They provided samples uniform in age for the species on a given sampling date, and showed the progressive changes due to advancing age throughout the season. A variation in age of leaf included in a sample will increase variability of composition within a sample and between duplicate samples. Each sample was a composite of 100 leaves from four or six trees of one variety, depending on the planting arrangement.

The objective of these analyses was to disclose differences, if any, between plots; therefore, few complete seasonal graphs were obtained in earlier years of the experiment. When the usefulness of such graphs was indicated by other investigations, graphs were obtained for these plots, also, starting in 1945. The years 1949, 1950, and 1951 represent seasons during which samples were taken at approximately monthly intervals, starting after the leaves had reached full size.

The plot arrangement was described in detail by Proebsting (1929). A brief description is: In Block A, French prunes planted in 1935 were designated A1; planted in 1922, A2; peaches planted in 1943, A3; apricots

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planted in 1943, A5; planted in 1922, A6; peaches planted in 1943, A7; and pears planted in 1928, A8. In Block B, pears planted in 1923 were called B1; prunes planted in 1923, B2; peaches planted in 1943, B3; apricots planted in 1943, B5; planted in 1923, B6; peaches planted in 1923, B7; and pears planted in 1928, B8. All prunes were propagated on Myrobalan rootstock, peaches on peach, and apricots on apricot. Pears in A8 and B8 were on French stock and in B1 on Japanese pear. In brief, three clean-cultivated check treatments were compared with single treatments of an annual summer legume, an annual winter legume, an annual winter nonlegume and alfalfa sod in duplicate plantings.

Originally each block consisted of two rows each of eight species. Each plot contained six trees. From time to time, as some of these plantings outlived their experimental usefulness, the trees were removed and replaced. In the process, almonds, Japanese plums, apples, and cherries were eliminated. The data presented are limited to the four remaining species: prunes, peaches, apricots, and pears.

A total of 294 seasonal graphs for each of five nutrient elements was secured in these three years. Space does not permit presentation of all these data. Graphs representing individual plots are shown for N for a single season, 1951, for all species and for K in apricots to show variability among plots and any differences, due to treatment, that might appear. Also shown are averages of the seven plots of each species, age, and replication for each year to show seasonal variation and to emphasize species differences in the absorption of the elements reported.

PRESENTATION OF DATA

Total Nitrogen

The total nitrogen, expressed as per cent dry weight, is shown in figures 1 to 20. These graphs indicate the changes for the 1951 season of 98 plots, and the differences of average values for the three years. They are presented in more detail than for the other elements because of the importance of N in the nutritional picture and its common use in the fertilizer program of California deciduous orchards.

Prunes. The individual graphs for the 21 plots of prunes (figures 1 to 3) show a fairly uniform drop in nitrogen content throughout the season. There seemed to be no reflection of treatment. A drop of 30 to 50 per cent occurred between time of initial sampling and the end of the season. The graphs of averages for seven plots each of A2 and B2 (fig. 4) for the three years showed rather uniform slopes for all three sets for 1949 and for 1951. The drop in 1951 was less than in 1949. The 1950 curves all showed a more rapid drop in midsummer, which reached somewhat lower values in late summer than in the other years. It should be noted that this was the year of light crop. These prunes bore very heavily in 1949 and 1951. It might be expected that a heavy crop would compete with the leaves for nitrogen but this seems not to have been the case. An alternative hypothesis might be that with less vegetative growth in heavy crop years, less nitrogen per leaf might be withdrawn.

Peaches. The graphs of individual peach plots (figures 5 to 8) resemble those of the prunes. The general level was slightly higher in the peaches. There was some indication of lower values in the rye plots than in the other treatments. All four sets of average curves (figures 9 and 10) for 1951 show less steep slopes due to much lower values early in the season than for the 1949 and 1950 data. Average mean daily temperatures for the three weeks' period prior to start of sampling were 65.5° F in 1949, 61.4° in 1950, and 55.7° in 1951. Whether this low temperature influenced the nitrogen metabolism to a degree that would account for the observed differences is speculative. These three years illustrate the differences in curves because of season. The 1949 graphs showed a fairly uniform drop throughout the season. The 1950 graphs dropped rapidly to the middle of July with a relatively flat or even slightly rising value during the ensuing months, followed in turn by a slight drop late in the season. Samples taken in July—the time often recommended for single samples—have shown differences as great as 20 per cent in successive years.

Apricots. The apricot graphs (figures 11 to 16) were quite similar to those for the peach, both in order of magnitude and in seasonal behavior. The early season samples in 1951 are not as greatly different from the others as are the samples of peaches. Seasonal graphs for all four series tended to be grouped together, as were those for the other species.

Pears. The pears (figures 17 to 20) generally followed the pattern set by the peaches and prunes. Like the peaches, the early season levels in 1951 (figure 20) were low compared with the preceding two years; they gave a more moderate slope than in 1949 or 1950. The 1950 curves exhibited unusual irregularity. There was considerable spread between the averages of the three series for the May sampling; and two of the three series showed a sharp drop to mid-July, similar to that shown by the peaches and prunes the same year. The order of magnitude of the nitrogen content was the same as that of prunes.

Potassium

The widely accepted pattern for seasonal change in potassium content of leaves is a high initial content which decreases rapidly until early summer, a relatively constant value through midsummer, and a final decrease until leaf fall. This pattern is explained by the tendency for potassium to be high in meristematic and young tissues. The final drop is explained as migration from the leaf to stem prior to abscission.

Prunes. The graphs for prunes (fig. 21) fail to follow this pattern more often than they follow it. An initial drop usually occurred in 1949 and 1950, but not in 1951. The midsummer flat region appears in 1950 but not in 1949 or 1951. No late sample was secured in 1951, but there was no late drop in 1949 and little if any in 1950. The August samples in 1951, taken after harvest, were highly variable, one series averaging lower and the other two higher than the July figures. The 1950 samples are higher than the other two years. This was the year of light crop. This is in contrast to the nitrogen content, which was low in 1950. It should be noted that severe leaf scorch and dieback developed in these trees in both 1949 and 1951—years of heavy crops. These symptoms were absent in 1950. Trees were sampled individually

in 1951 after harvest and were graded on a scale of 0 to 5 in severity of scorch. All trees with less than 1.0 per cent K graded 2 or above. The only trees free from scorch had 1.8 per cent K or more. Trees showing slight scorch (group 1) varied in K content from 1.0 to 2.0 per cent. The highly variable figures for this sampling period referred to above may be associated in part with differences in yield and in part with injury occurring in the earlier year of scorch—1949.

There is a slight indication of lower K in the alfalfa plots.

Peaches. The K curves for peaches (fig. 22) present some interesting variations. Variations often exceeded the usual sampling error, but no treatment is uniformly high or low throughout all comparative series. Perhaps the alfalfa and the south check are more often low and the rye plots more often high than otherwise, but there are enough exceptions to make such interpretation tentative. The 1950 season shows a wider range than do either 1949 or 1951.

The curves for averages of these plots show moderately sharp drops in early season in 1949, gentler reductions to August followed by a slight rise at the end of the season. In 1950, one series shows a nearly straight line decrease throughout the season. The other three show a slight late season increase. The whole character of the curves is different in 1951. Instead of an initial fall, there is a rise in all four series, followed by a midsummer drop. Midseason values show an increase from year to year, with July figures being almost double the 1949 values in the 1951 data. It is interesting that all of the 1949 values after the May sampling fall below 1.0 per cent. There has been no appearance of potassium deficiency symptoms in these trees, although an occasional single plot sample in 1949 dropped below .5 per cent K. 1949, the year of low K content, was the year of high nitrogen content.

Apricots. The season curves for apricots (figures 23 and 25 to 28) are radically different from the others, except perhaps the peach curves for 1951. They are, therefore, presented in more detail than the other species. In each year for practically all plots there is an initial increase instead of a decrease. This was noted first in 1945. In the three years under consideration here, the only exceptions occurred in 1950 when eight of the 28 plots failed to show increases between the first and second dates of sampling. The effect of treatment seems more marked and more consistent than in the other species. The alfalfa usually is the lowest. The summer cover plots often are less than the checks but are higher than the alfalfa. The rye plots tend to be high. The variation among plots is the greatest for any species. This is reflected in the curves for averages.

Seasonally, the 1949 values are low and the 1951 high, as was true with peaches. The 1951 curves are unique in attaining maxima at the August sampling. The mid- and late-season figures are well above the K content for the other species for those periods.

Pears. The K in pear leaves (fig. 24) approaches the "standard" pattern more closely than the other species considered here. There is no consistent difference between treatments. The curves of averages vary from season to season with the 1949 curves tending to be lower and the 1950 ones higher than the 1951 values. The curves for trees on oriental rootstock (Series B1)

seem to have a wider spread between spring and summer than the trees on French root. In 1949 the drop from May to August is nearly 60 per cent.

Phosphorus

Prunes. The phosphorous content of prune leaves (fig. 29) followed a fairly regular course affected little by the treatment. The maximum values occurred at the time of initial sampling. The minima occurred after July 1 but the time varied. In 1949 the August and October values were about the same; in 1950 the final sample was the lowest, at the end of September; in 1951 there was a slight rise from July to August.

Peaches. The peach graphs (fig. 30) follow the prune curves in general character and in order of magnitude. There is again no apparent effect of treatment. The graphs of averages showed slight rises in both 1950 and 1951 at the end of the season. There was less differentiation from year to year than was evident in the nitrogen and potassium figures.

Apricots. The apricot graphs (fig. 31), as was the case with potassium, were less regular than the other species and were different in character. There was a tendency for the alfalfa plots to be low and perhaps for the rye to be high. Because there were such great differences among the plots, the averages are of less importance. They do, however, bear out the sharp contrast between the apricot and the other species considered. The early minima and the very large rises thereafter to late maxima set this species off by itself.

These apricot trees are more uniform in appearance and yield than most of the other species. They have shown no symptoms of abnormal nutrition. Growth and yield have been above average. The differences in composition found, therefore, are within the range which must be called "normal" for the situation in which they are growing. Seasonal differences in pattern and level occurred but were less conspicuous than with potassium. It should also be noted that the phosphorous level is much greater for the apricot than for the other species.

Pear. The pear plots, shown in figure 32, follow the same pattern as that of the peach, except on a slightly lower level.

Calcium

In contrast to most of the curves for nitrogen, phosphorus, and potassium, those for calcium show minima at first sampling and increase throughout the season.

Prunes. Among the prune plots (fig. 33) there are no evident differences which can be ascribed to treatment. The 1949 values tend to be high and the 1950 low.

Peaches. The peach curves (fig. 34) constitute a more homogeneous group than do the prunes. They are a little higher, approach a straight-line increase more closely, and show less tendency toward seasonal variation than the prunes.

Apricots. Except that calcium content is higher in apricot leaves than in the leaves of other species, the curves (fig. 35) are much like the other species. No differentials have appeared either of treatment or season.

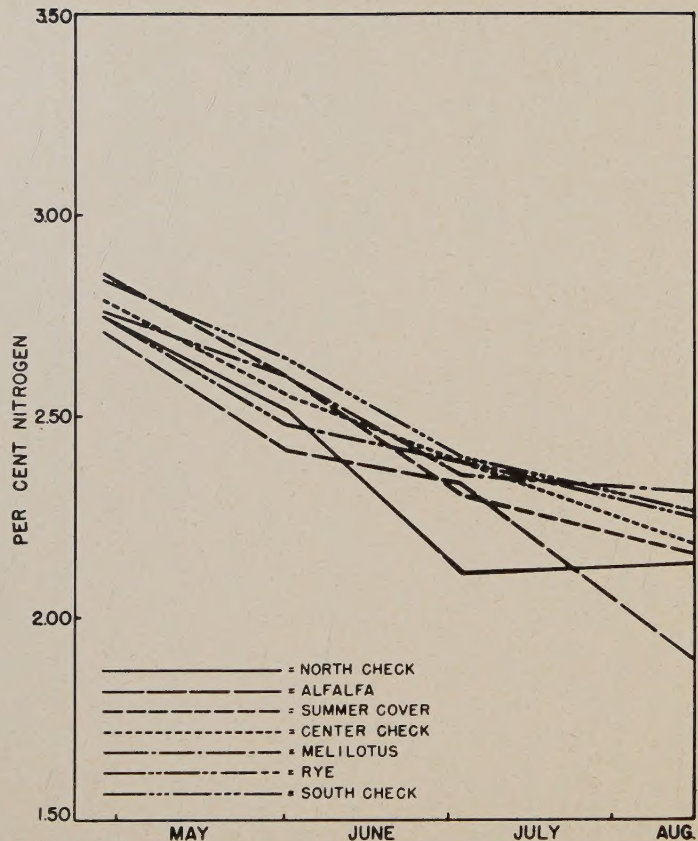

Fig. 1, series A1.

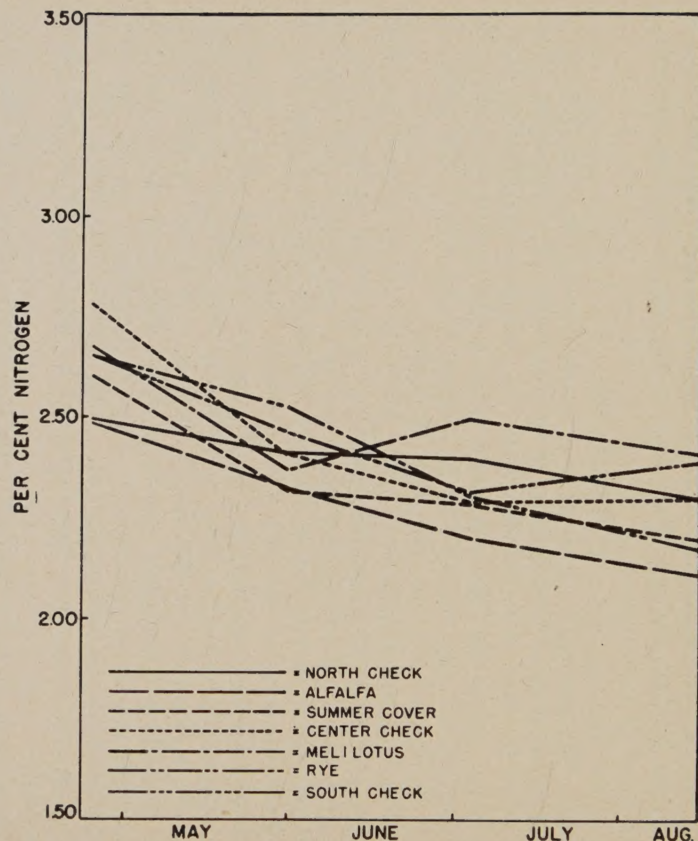

Fig. 2, series A2.

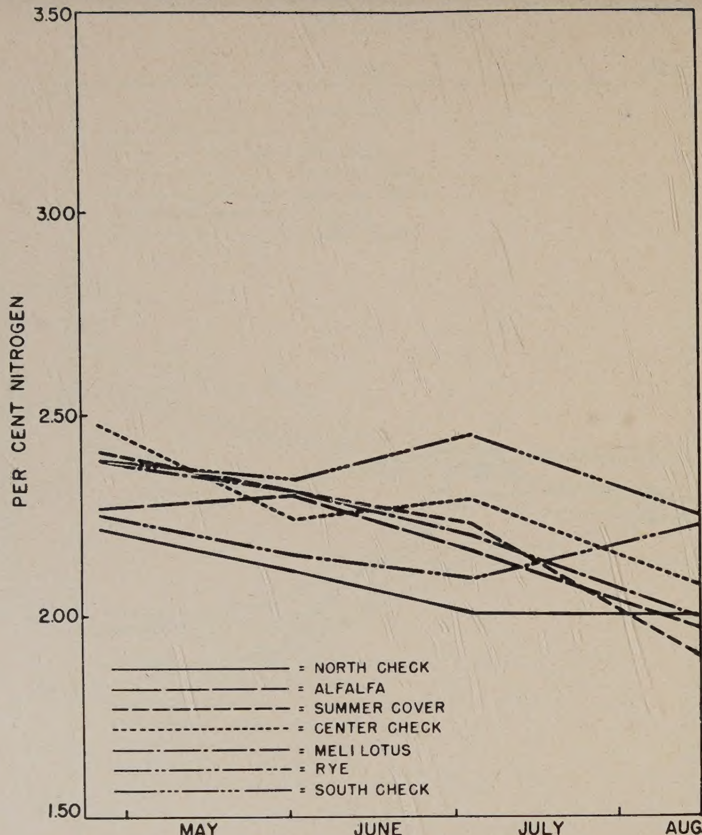

Fig. 3, series B2.

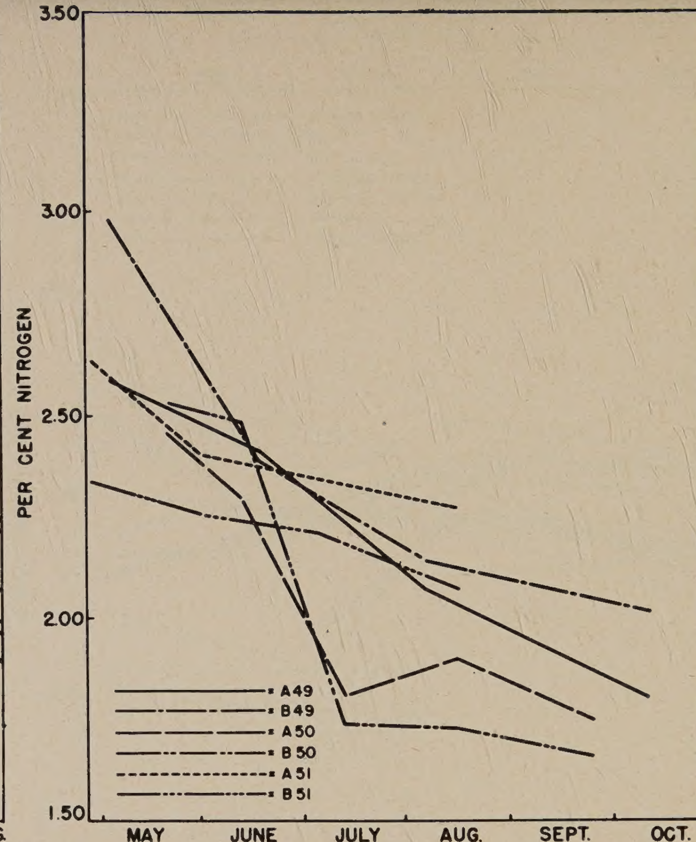

Fig. 4, averages of 7 plots, series A2 and B2, 1949–1951.

Figs. 1–4. Total N of prune leaves, 1951, in per cent dry weight.

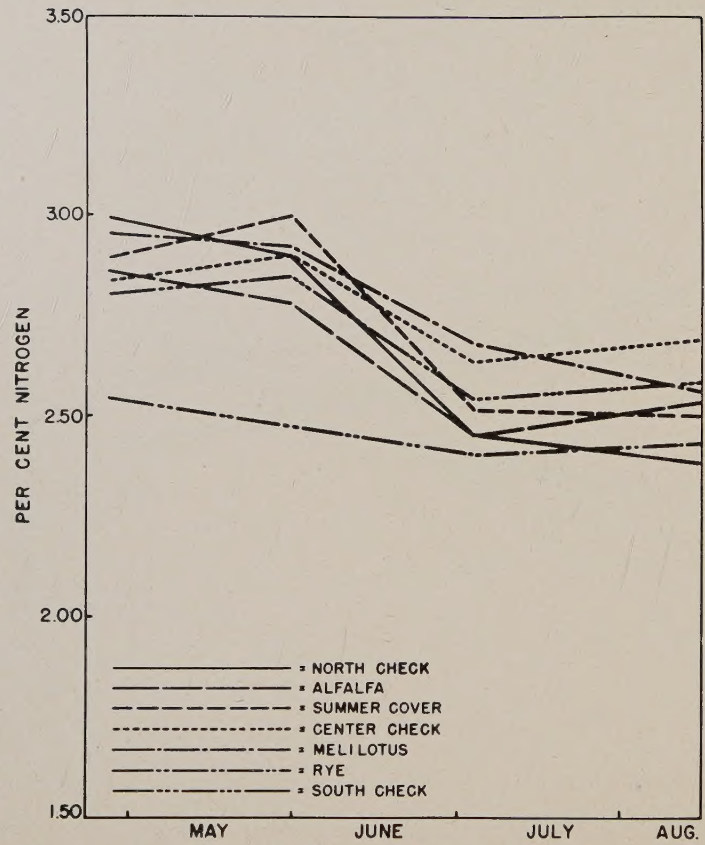

Fig. 5, series A3.

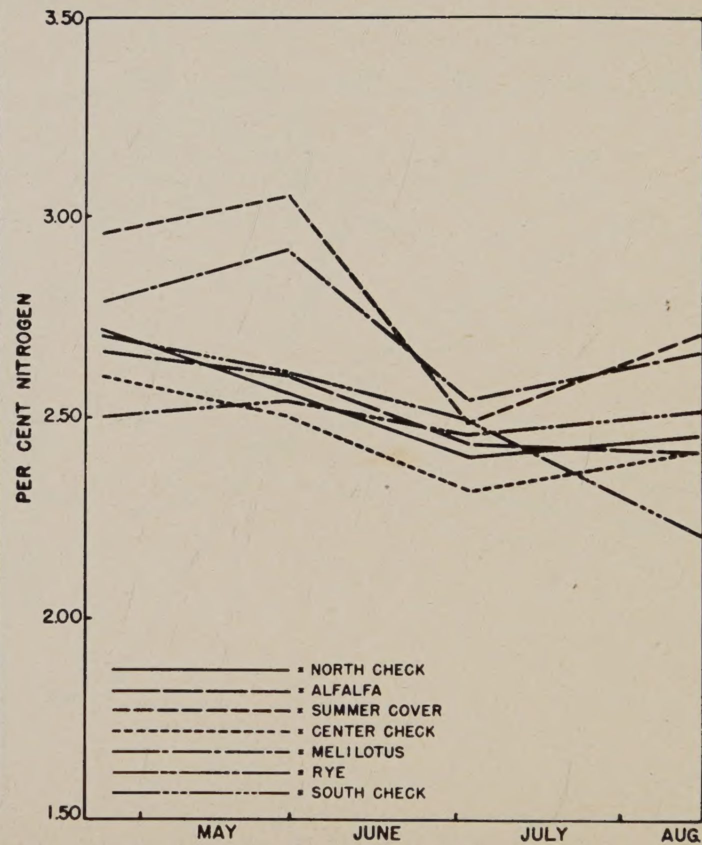

Fig. 6, series B3.

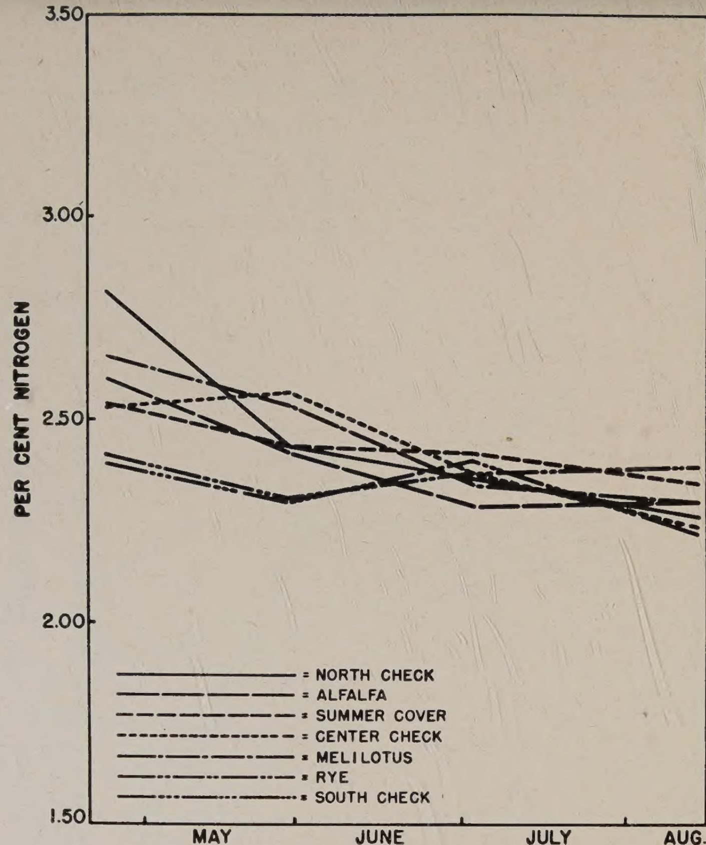

Fig. 7, series A7.

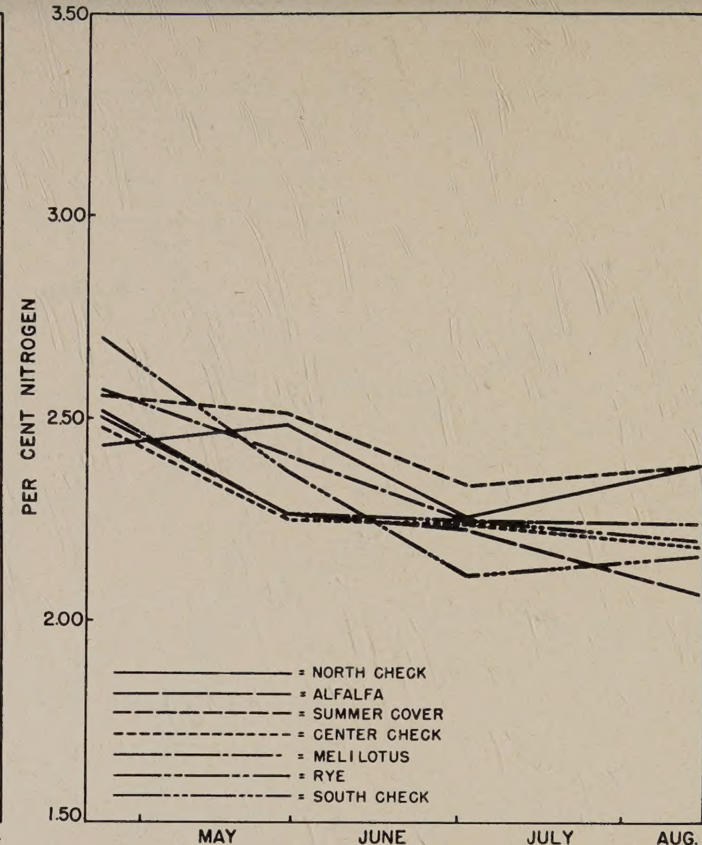

Fig. 8, series B7.

Figs. 5–8. Total N of peach leaves, 1951, in per cent dry weight.

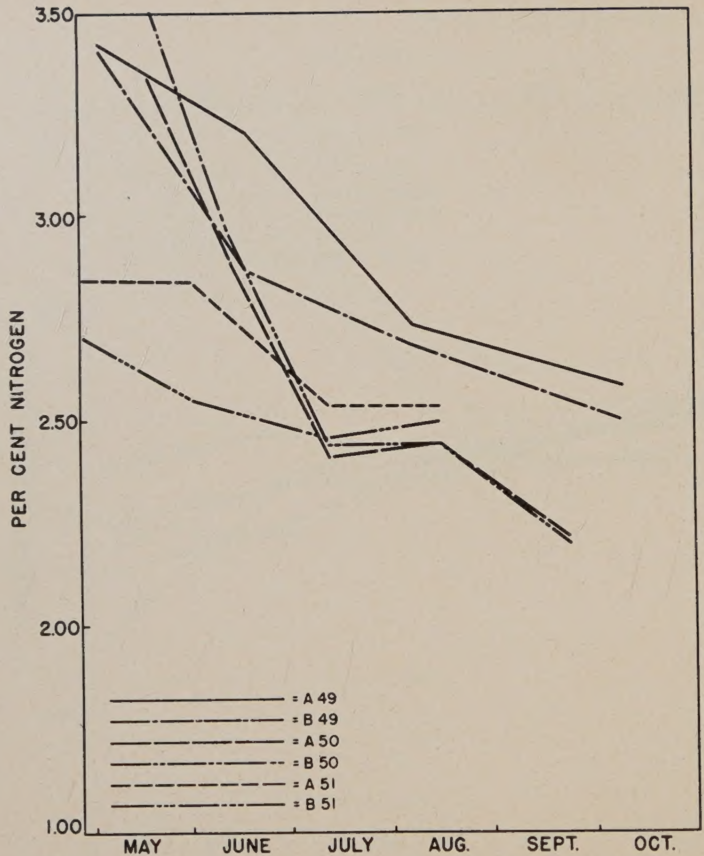

Fig. 9, series A3 and B3.

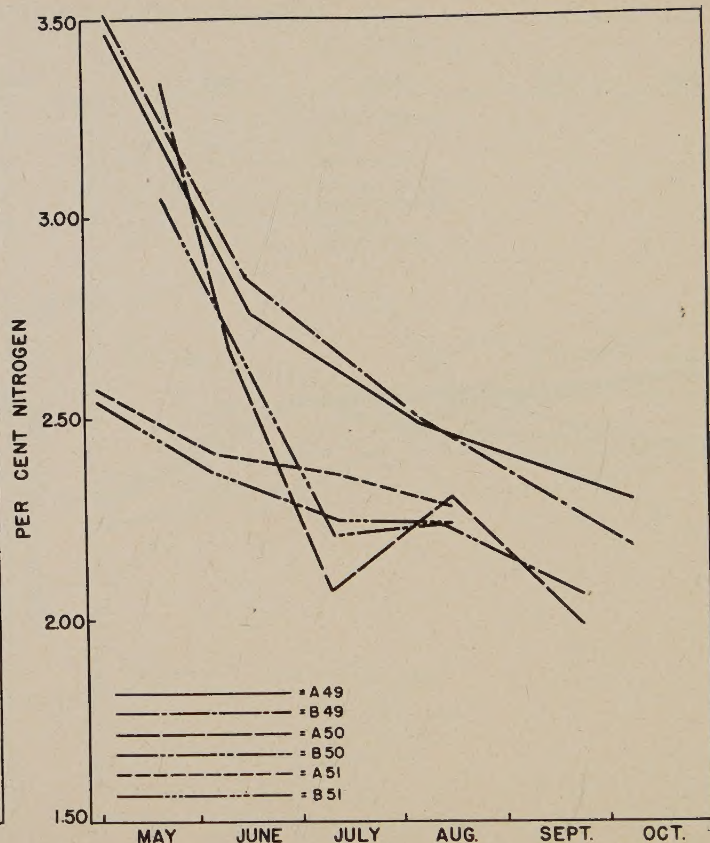

Fig. 10, series A7 and B7.

Figs. 9–10. Total N of peach leaves, averages of 7 plots, 1949–1951.

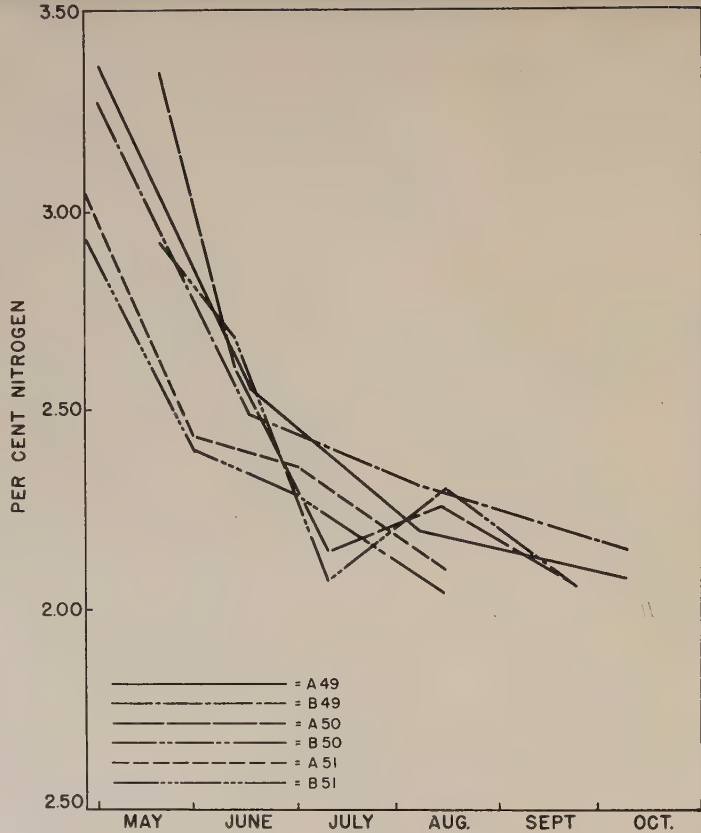

Fig. 11, series A5 and B5.

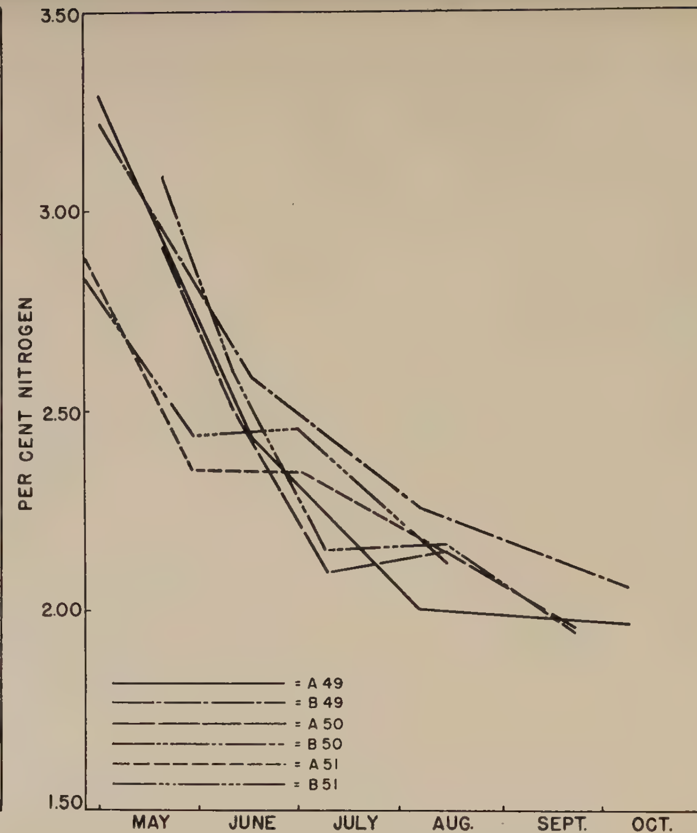

Fig. 12, series A6 and B6.

Figs. 11–12. Total N of apricot leaves, averages of 7 plots, 1949–1951.

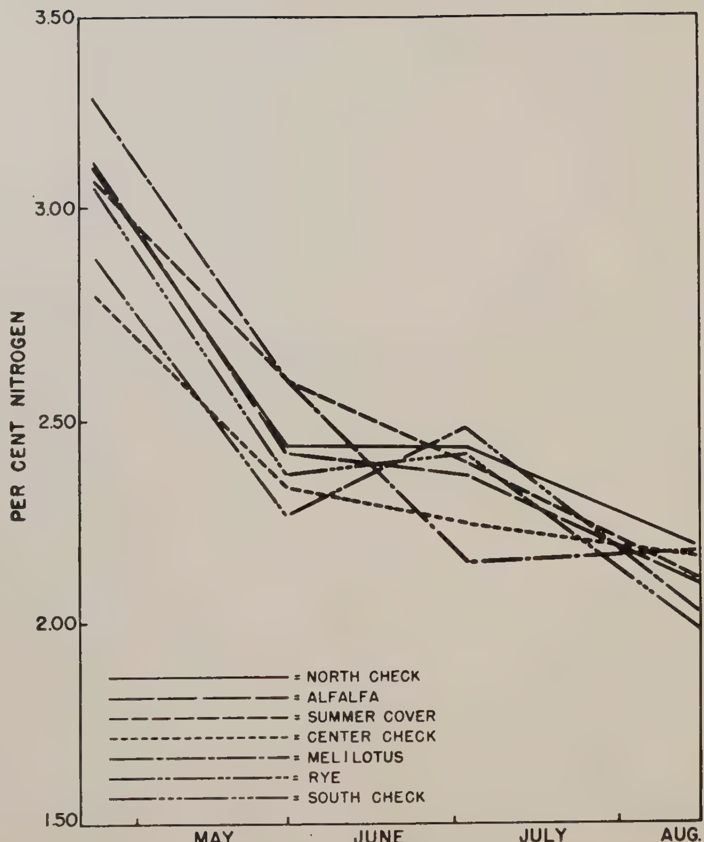

Fig. 13, series A5.

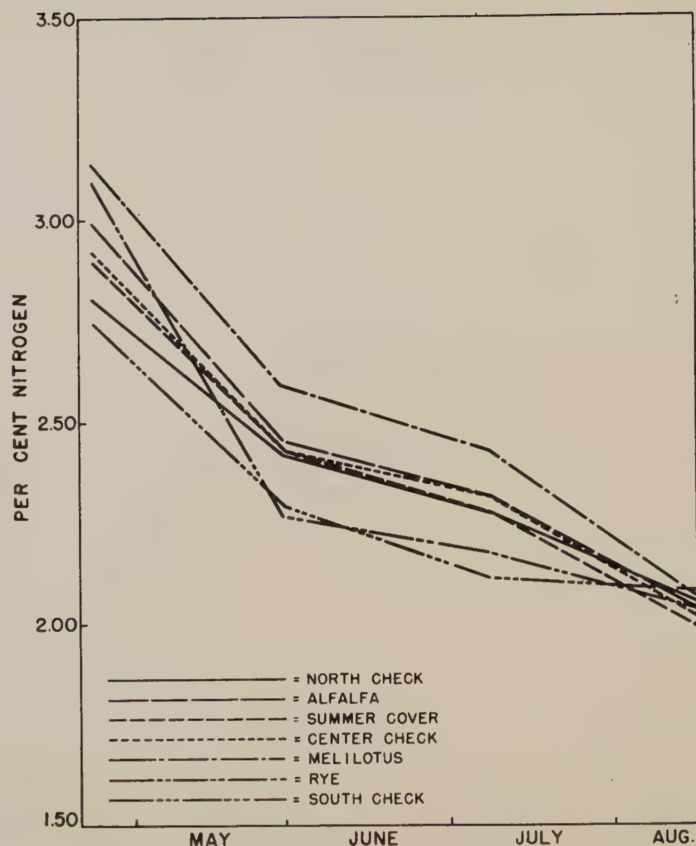

Fig. 14, series B5.

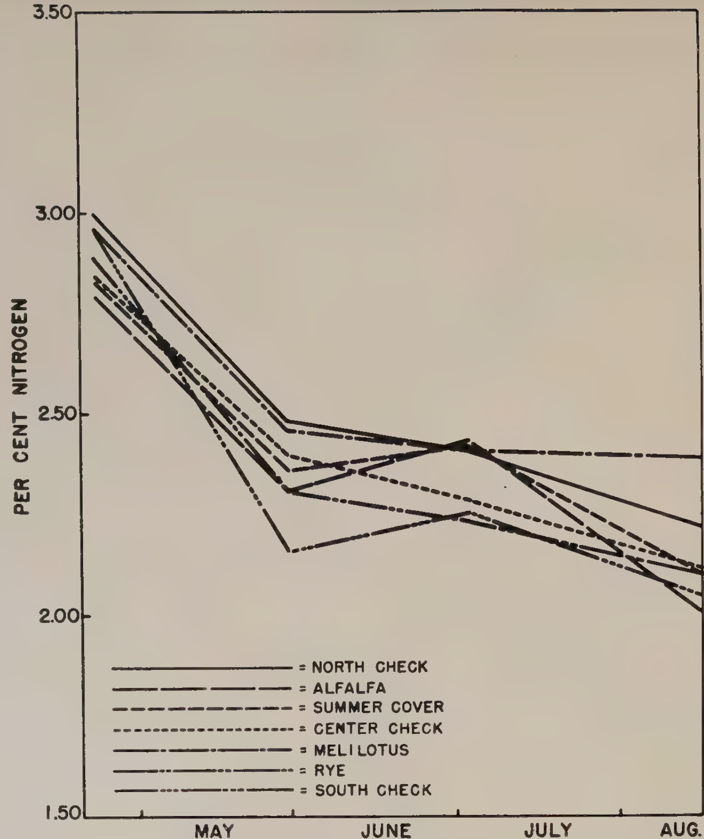

Fig. 15, series A6.

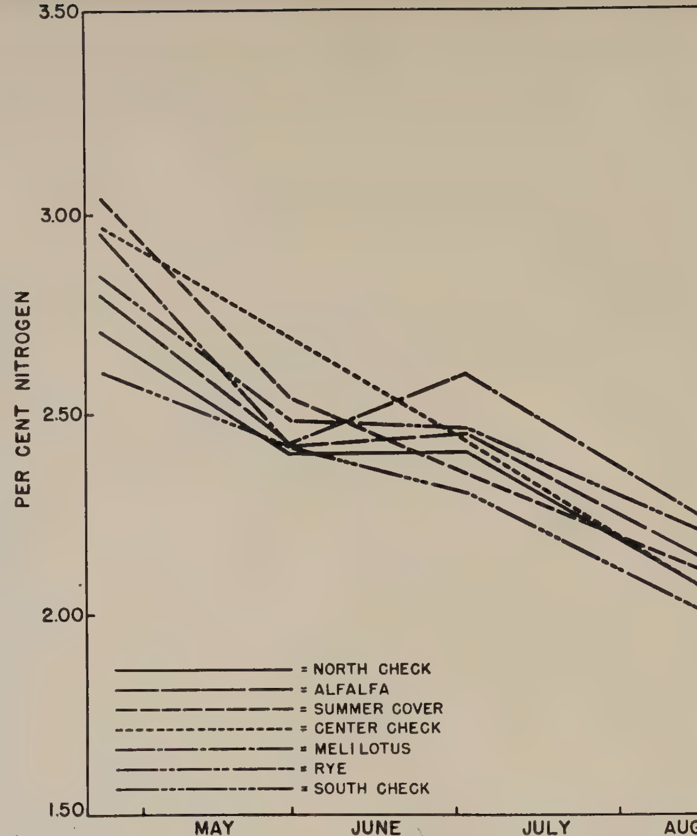

Fig. 16, series B6.

Figs. 13–16. Total N of apricot leaves, 1951, in per cent dry weight.

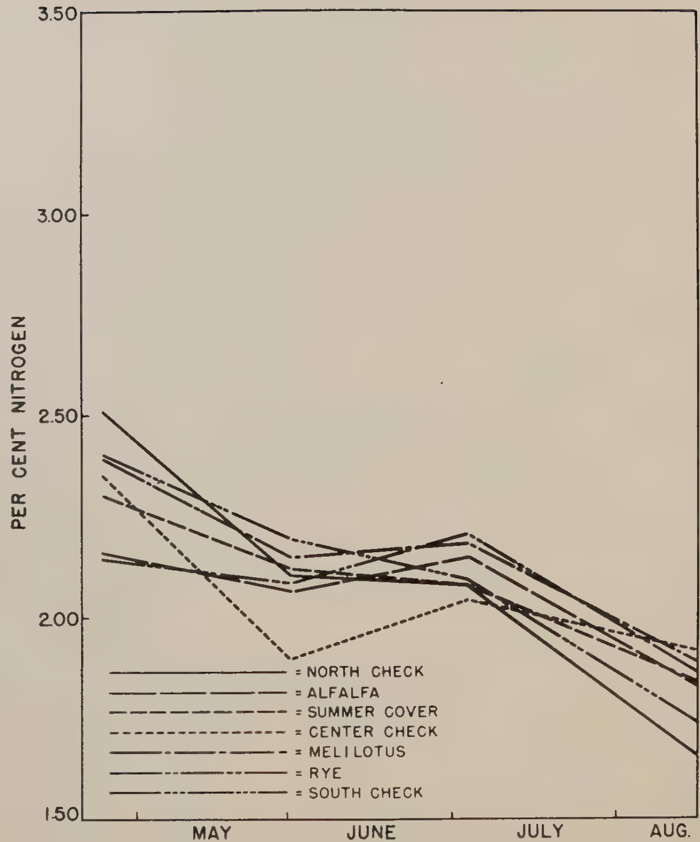

Fig. 17, series B1.

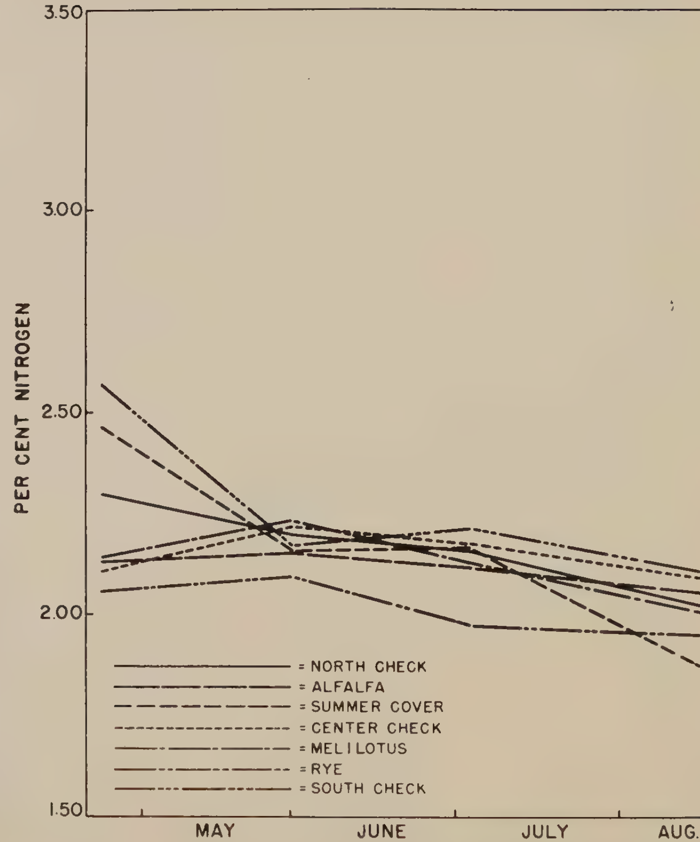

Fig. 18, series A8.

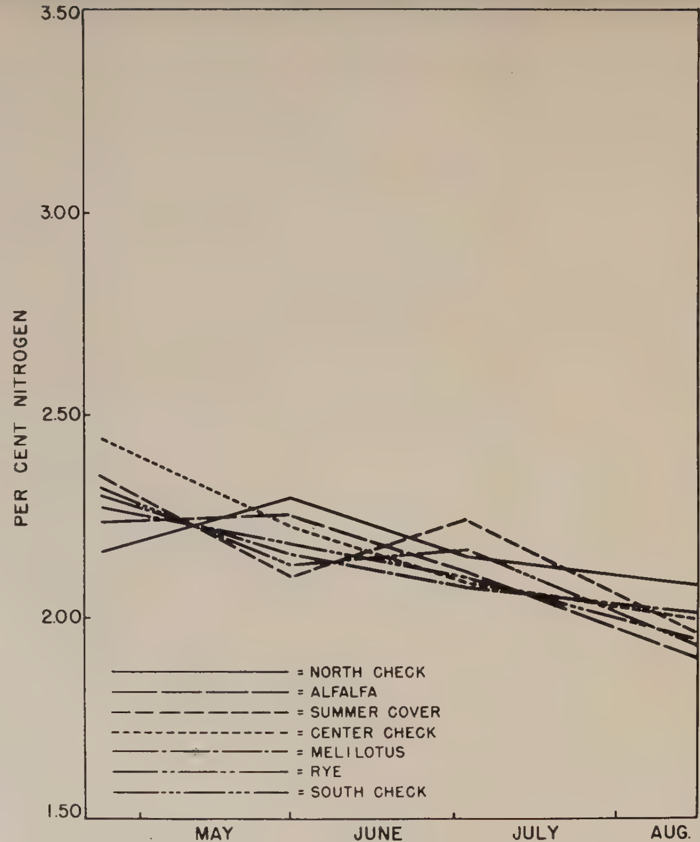

Fig. 19, series B8.

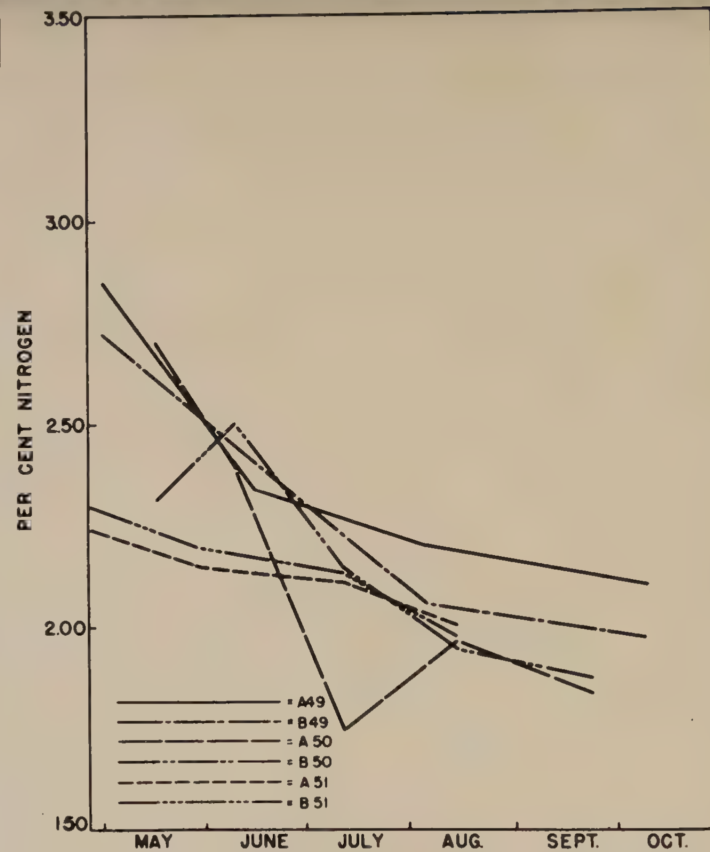

Fig. 20, averages of 7 plots, A8 and B8, 1949–1951.

Figs. 17–20. Total N of pear leaves, 1951, in per cent dry weight.

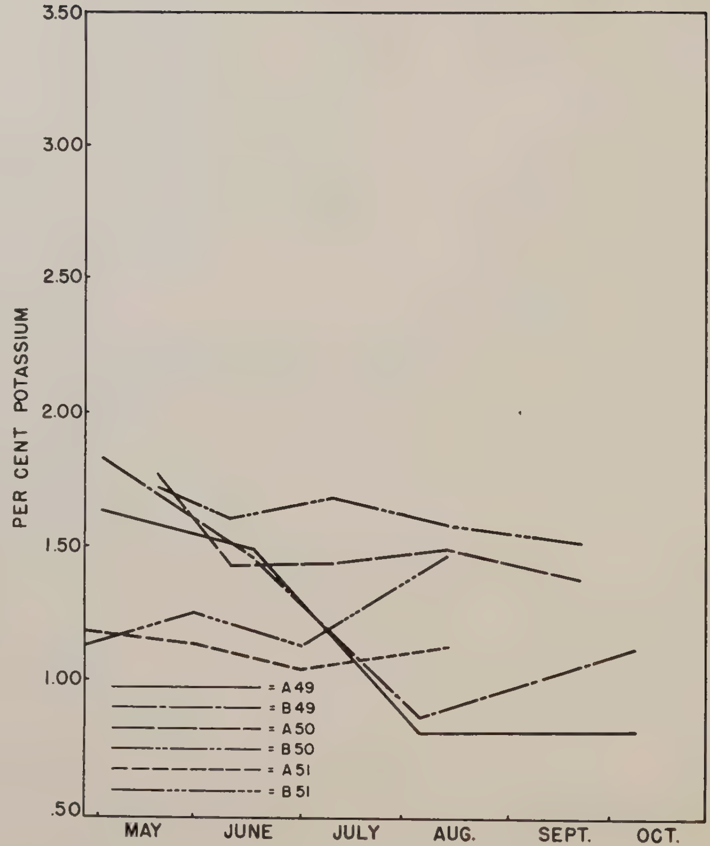

Fig. 21, prune series A2 and B2.

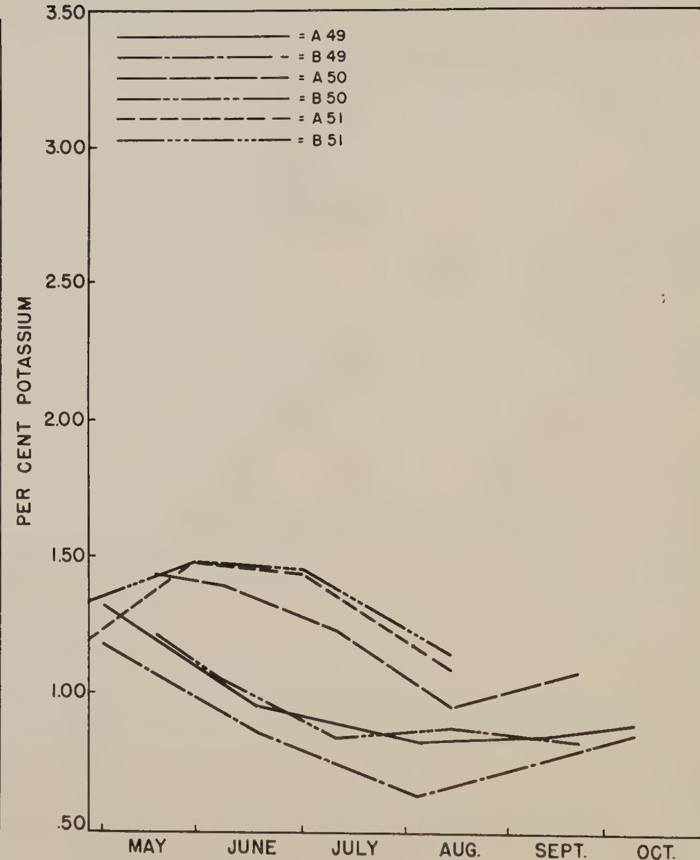

Fig. 22, peach series A3 and B3.

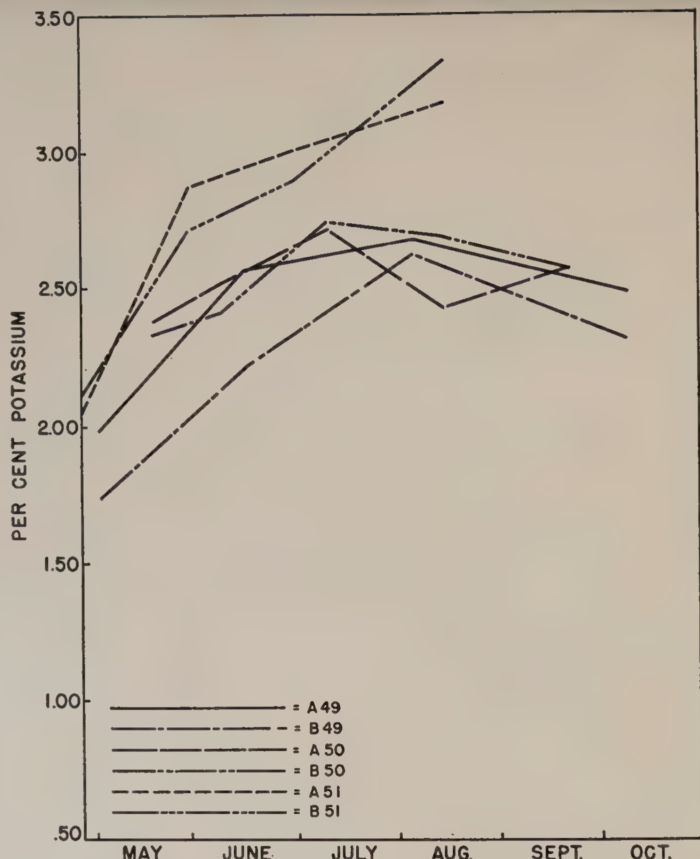

Fig. 23, apricot series A5 and B5.

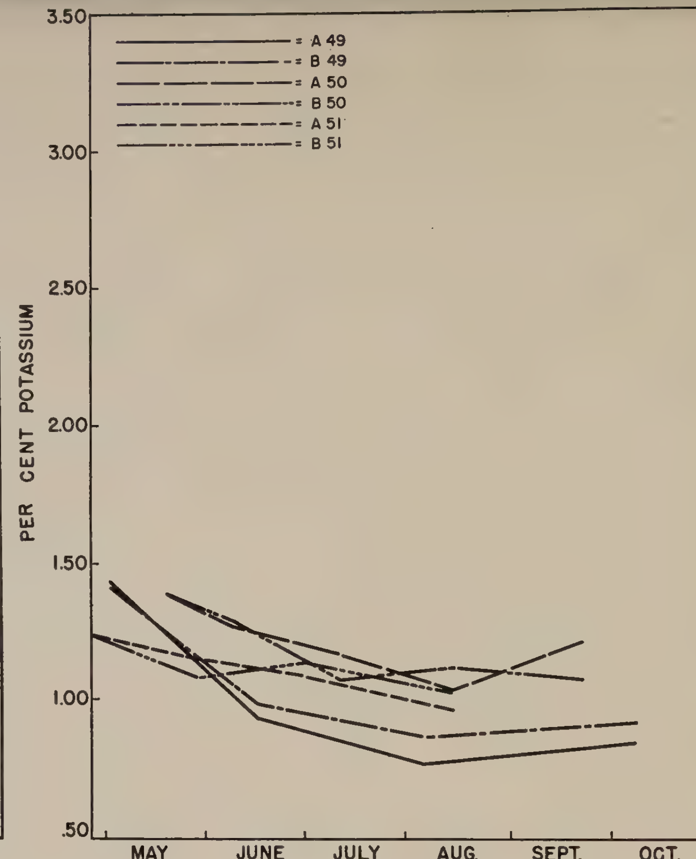

Fig. 24, pear series A8 and B8.

Figs. 21–24. K in leaves in per cent dry weight, averages of 7 plots, 1949–1951.

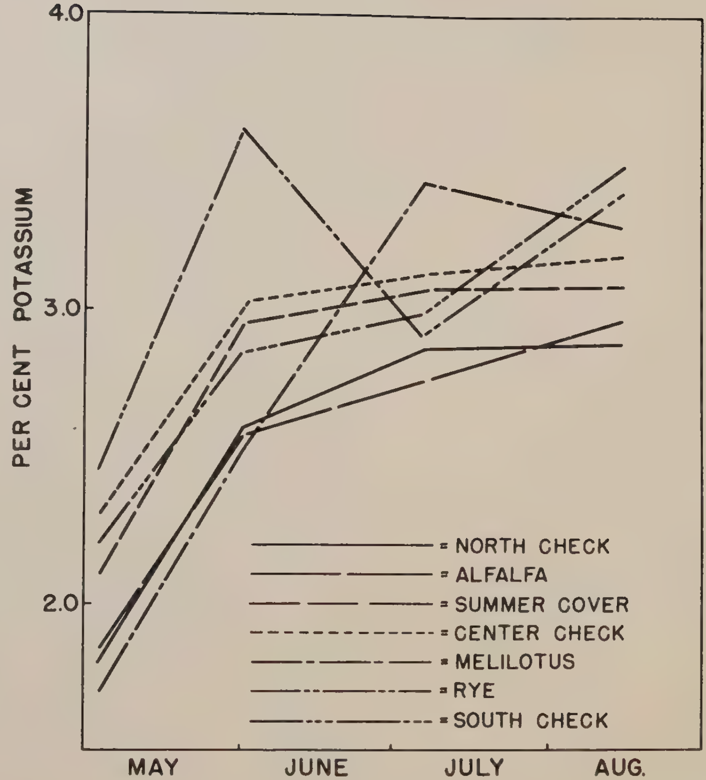

Fig. 25, series A5.

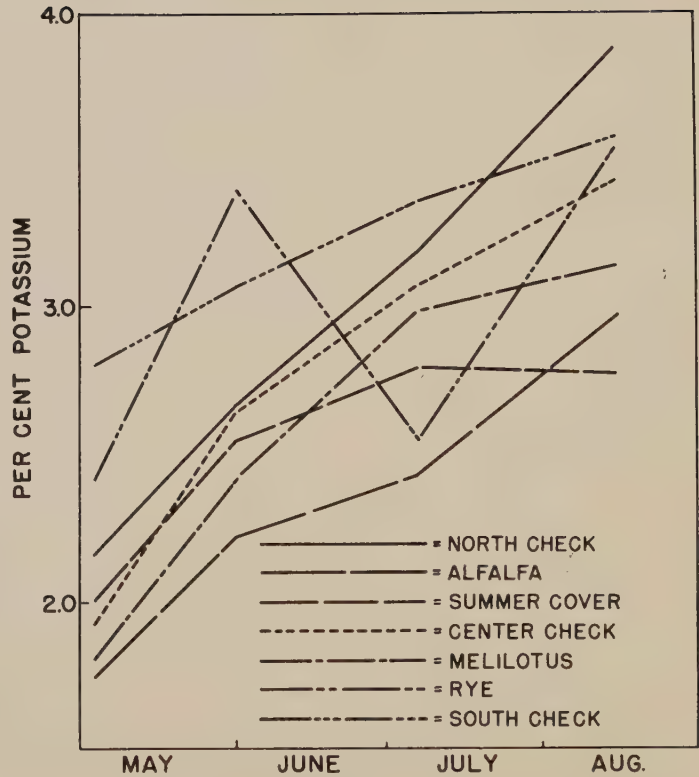

Fig. 26, series B5.

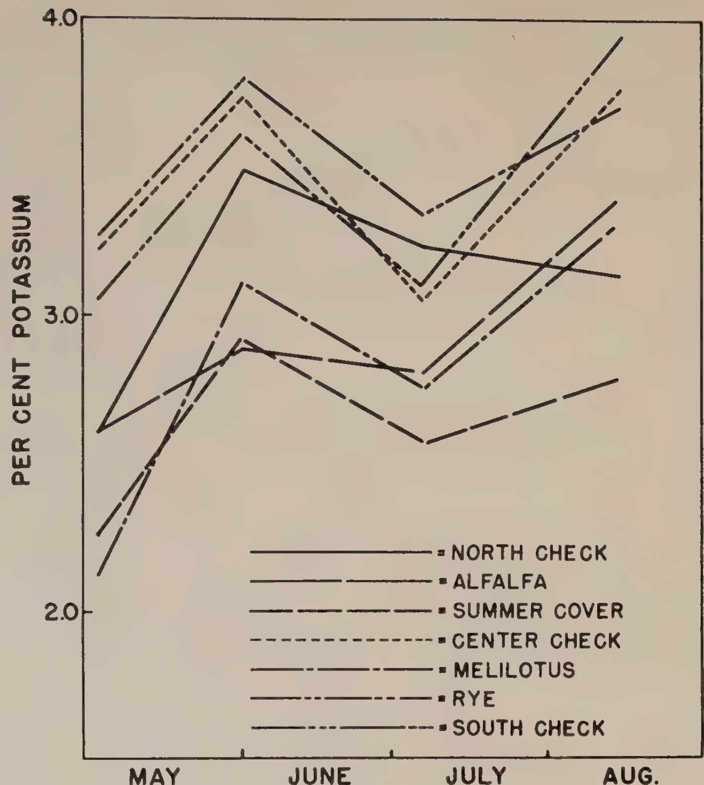

Fig. 27, series A6.

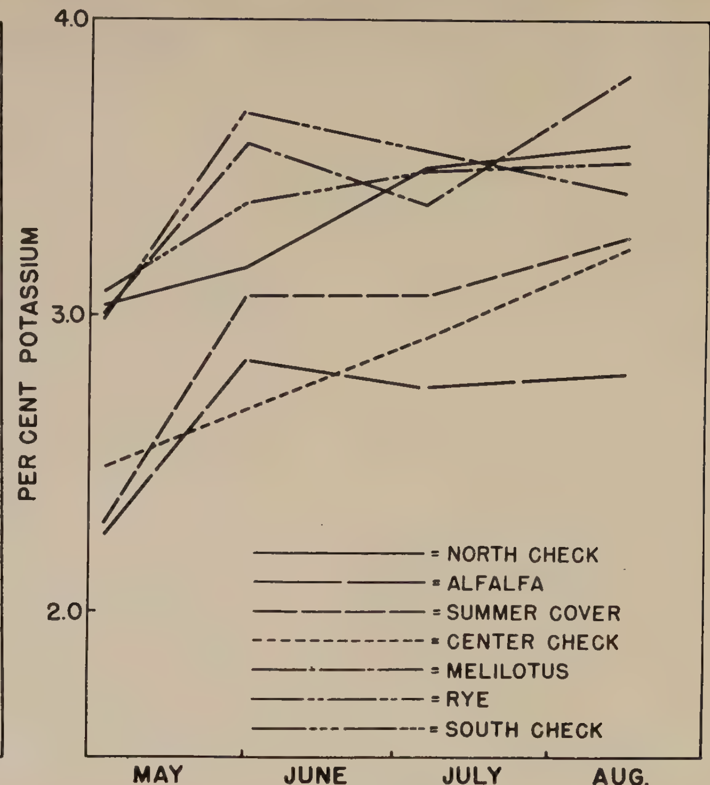

Fig. 28, series B6.

Figs. 25–28. K in apricot leaves, 1951, in per cent dry weight.

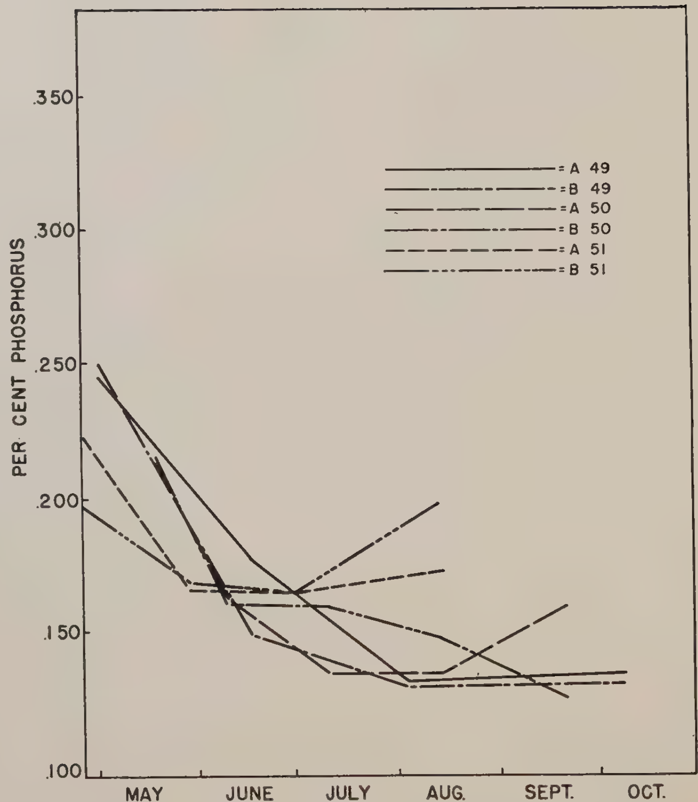

Fig. 29, prune series A2 and B2.

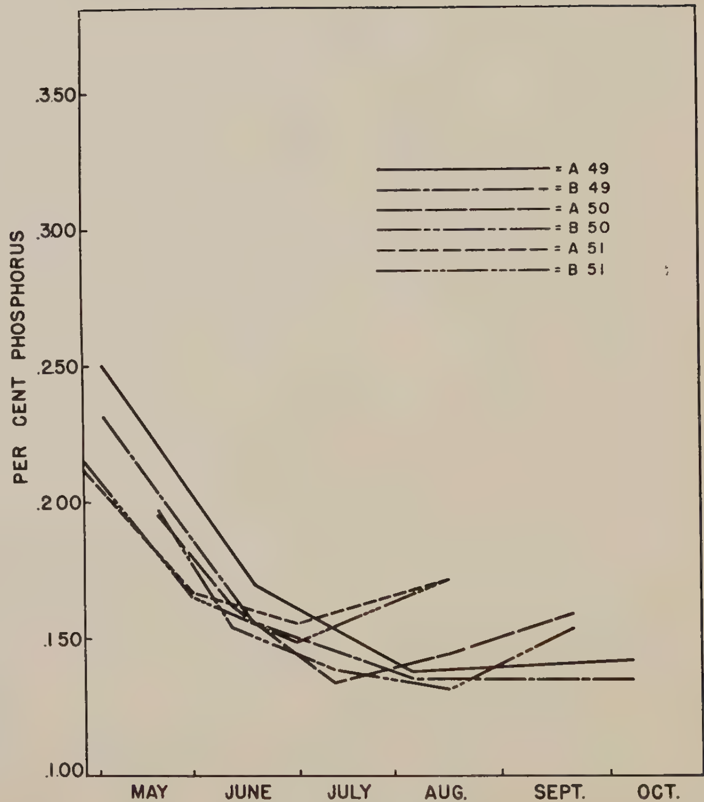

Fig. 30, peach series A3 and B3.

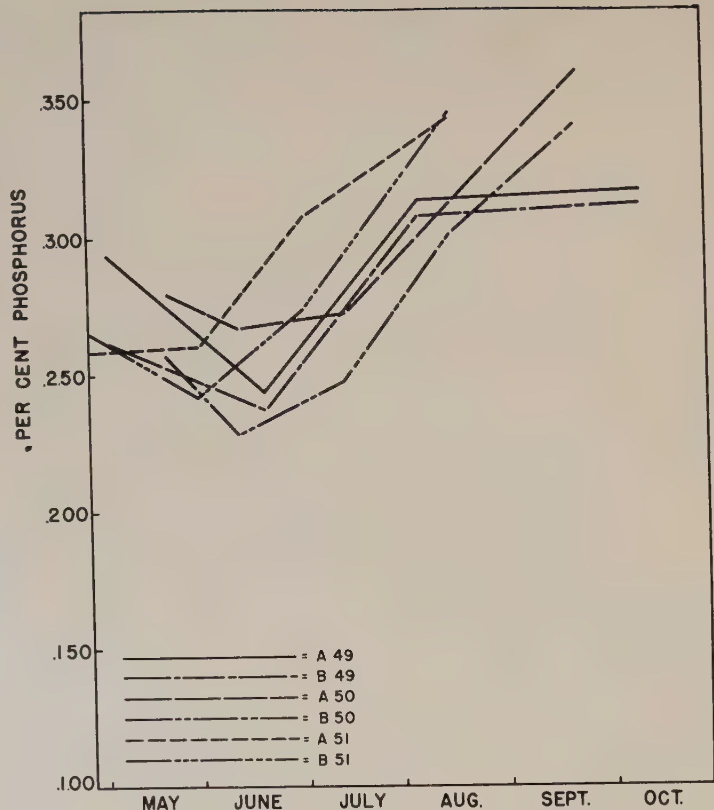

Fig. 31, apricot series A5 and B5.

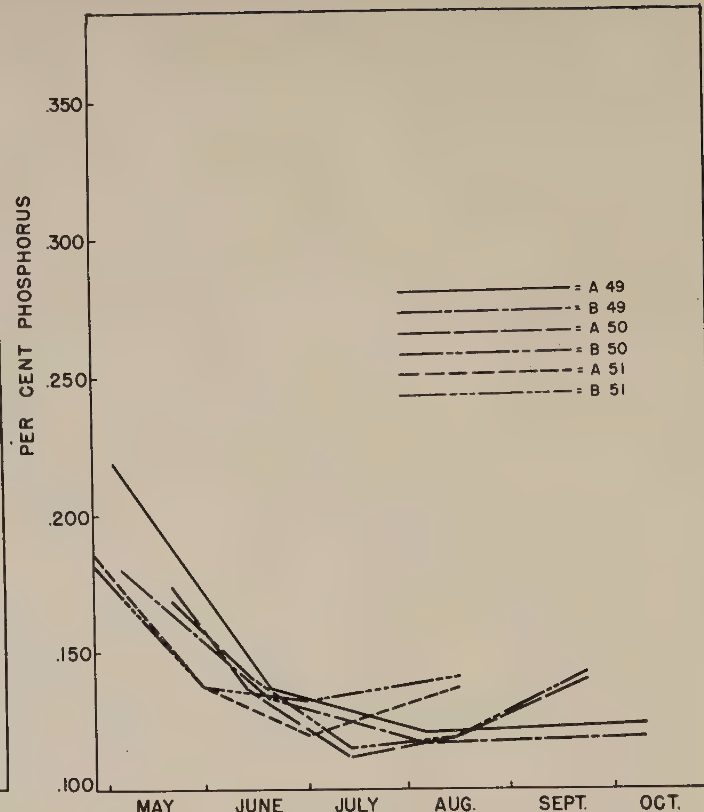

Fig. 32, pear series A8 and B8.

Figs. 29–32. P in leaves, in per cent dry weight, averages of 7 plots, 1949–1951.

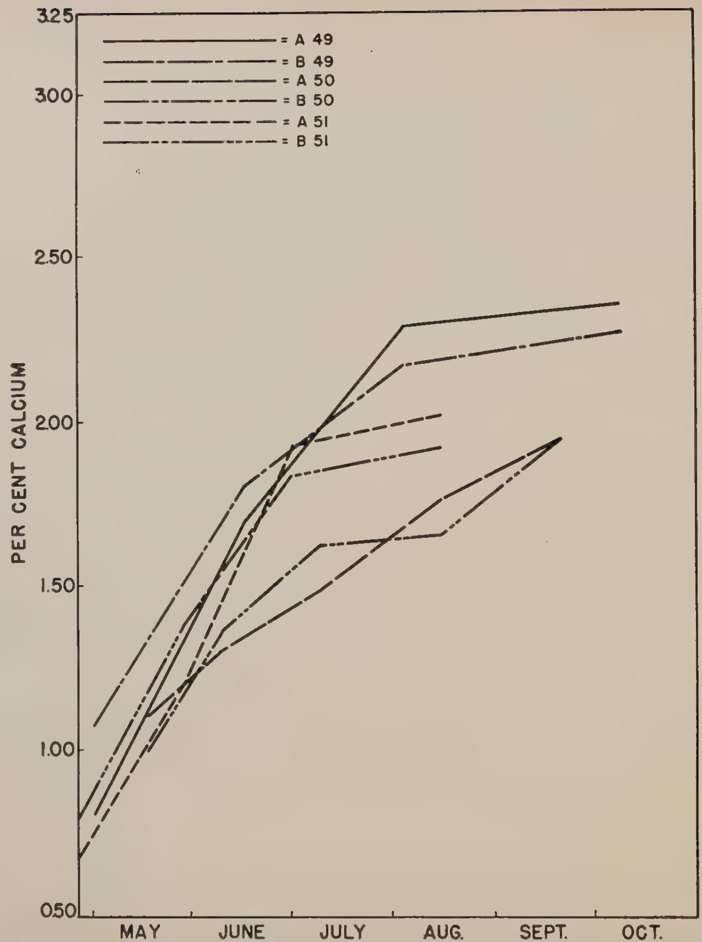

Fig. 33, prune series A2 and B2.

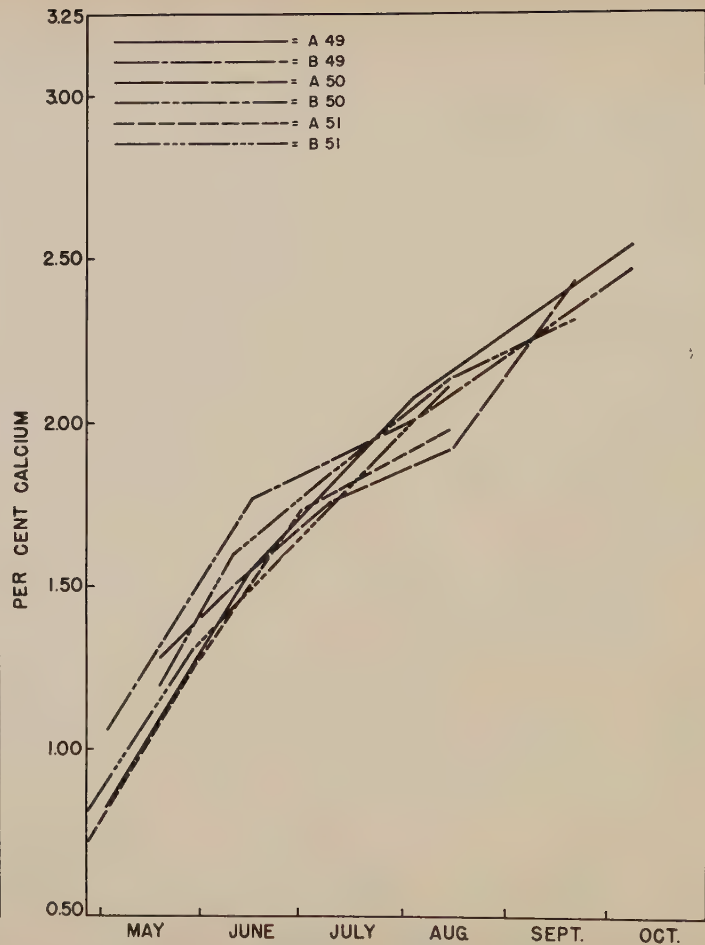

Fig. 34, peach series A3 and B3.

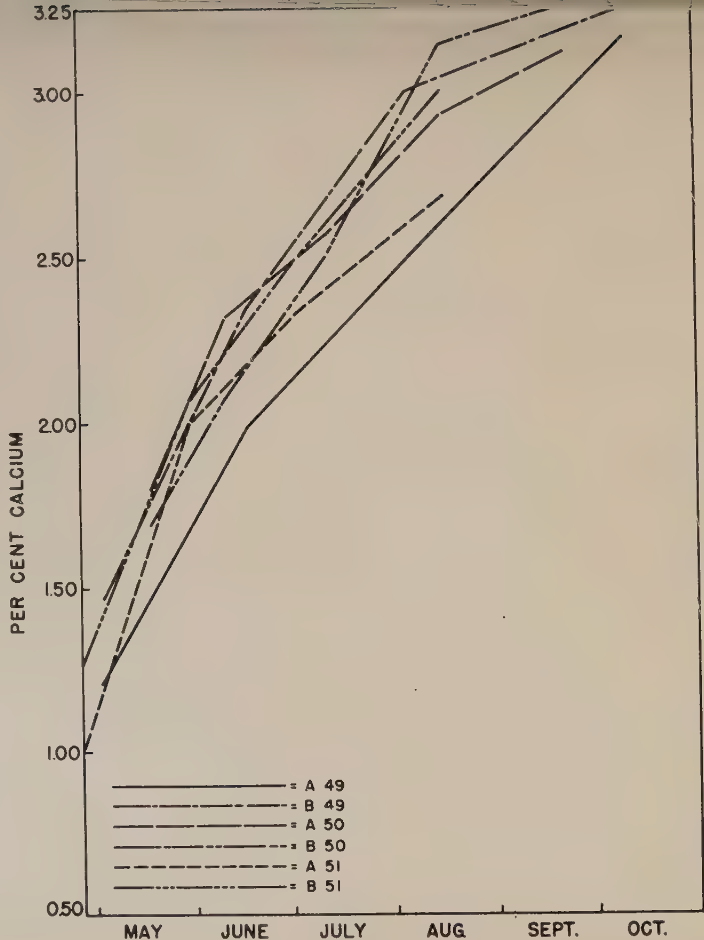

Fig. 35, apricot series A5 and B5.

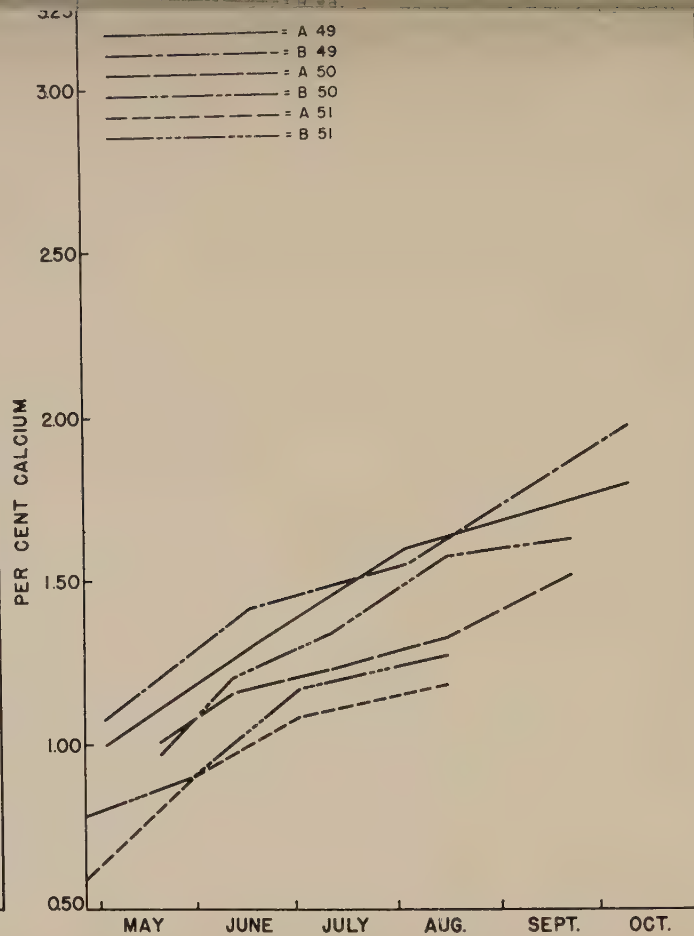

Fig. 36, pear series A8 and B8.

Figs. 33–36. Ca in leaves, in per cent dry weight, averages of 7 plots, 1949–1951.

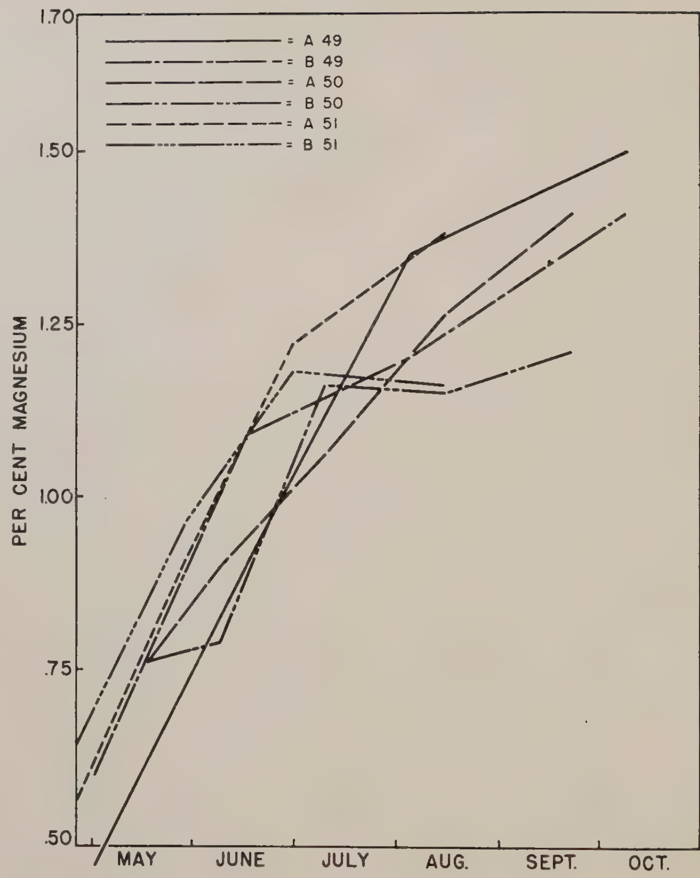

Fig. 37, prune series A2 and B2.

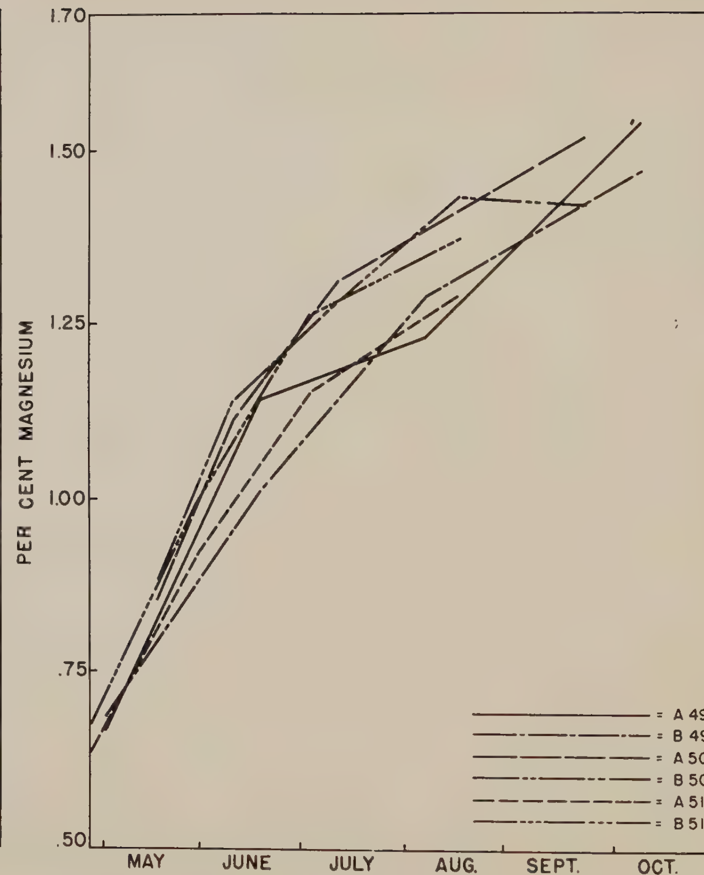

Fig. 38, peach series A3 and B3.

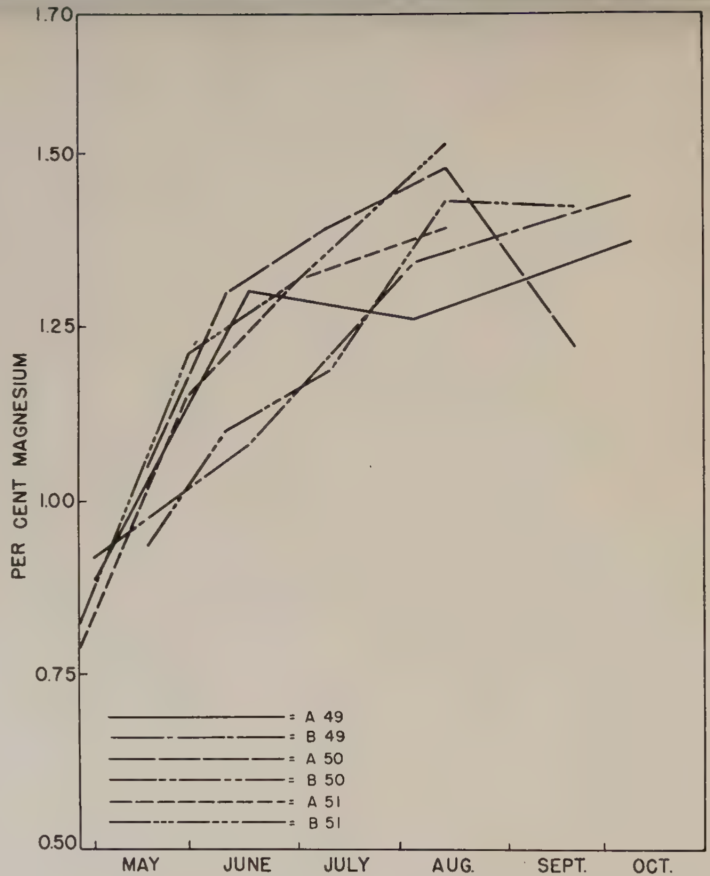

Fig. 39, apricot series A5 and B5.

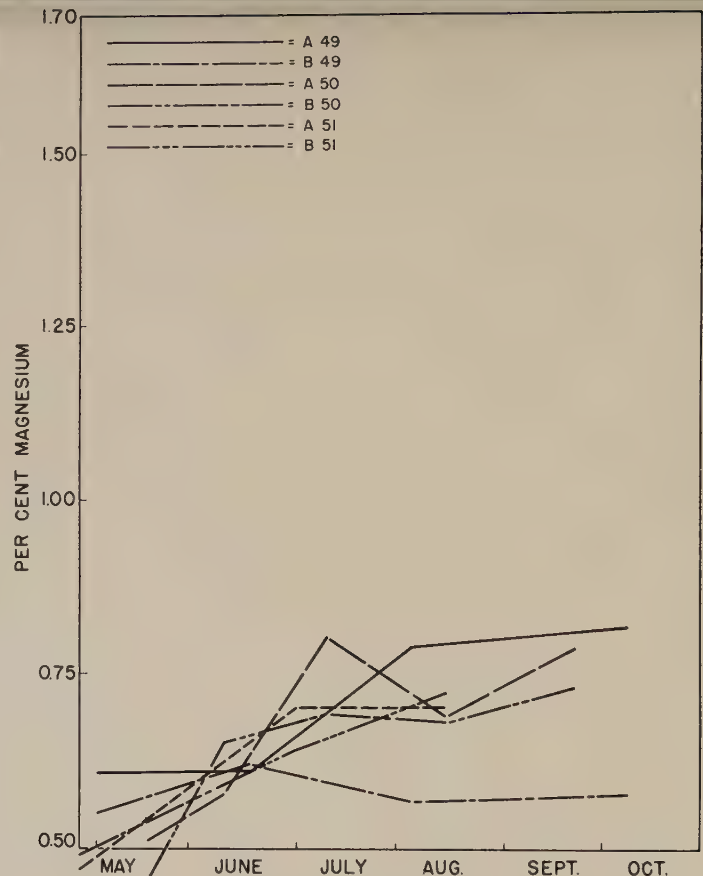

Fig. 40, pear series A8 and B8.

Figs. 37–40. Mg in leaves, in per cent dry weight, averages of 7 plots, 1949–1951.

Pears. The pear curves (fig. 36) are much like the prunes except at a lower level and with a more moderate slope. The 1949 values are high, the 1951 are low, but total spread is not great.

Magnesium

The magnesium content of the prune, peach, and apricot leaves (figures 37 to 39) is so nearly the same that all three species can be treated together. There is a steady increase throughout the season, the concentration roughly doubling by the end of the season. There are no consistent differences due to treatment or to season. The magnesium values are somewhat higher than those commonly reported. This is not surprising in view of the fact that magnesium is the dominant cation in both the soil solution and the exchange fraction below 4 feet. The extensive scorch associated with heavy crops of prunes, even without very low K values, may be influenced by the high magnesium.

The pears (fig. 40) stand out from the stone fruits in having lower values throughout the season, although they, too, show seasonal increases.

DISCUSSION

Although the data presented here were developed primarily to aid in interpreting the response of trees to differential covercropping and soil management, they may have some use in themselves. An increasing interest in leaf analysis as a diagnostic tool has been shown in recent years. The opportunity to compare species grown under uniform soil, climatic, and cultural conditions is not often afforded. The volume of data secured seems ample to give an idea of the variability one can expect both from the sampling standpoint and from the effect of season on the same trees.

The graphs of nitrogen content are representative of those found in other fruit districts with similar soil and climate. Although a nearly straight-line drop in percentage of N in leaves is very common and might be called "typical," variations have been observed in all species studied. It has not been possible to link all of these deviations to known factors. The values reported here, coming from trees of known performance, might serve as a basis of comparison for similar trees grown under other soil or climatic conditions.

The widest differences in seasonal composition of any of the elements reported here are found in potassium content. The "traditional" seasonal changes rarely appear in these data, nor do they resemble the spring minimum and August maximum reported by Lilleland (1932). Not only is there often an increase instead of a decrease in the early season, but the middle period rarely fails to show change, and the final period often shows an increase. The differences in seasonal changes among species are very striking.

Although no reason beyond species character can be assigned for these differences at the present time, their importance in interpreting data on leaf analyses is obvious. The fact that changes in composition at any given period in the life of a leaf may be of considerable magnitude would indicate caution in assigning limits for deficiency or excess. For example, limiting values are suggested by Goodall and Gregory (1947) for two of the species dealt with in this paper. Climatic and soil factors are neglected and time of

sampling either is ignored or is vague. We find in this orchard that K values may be below the indicated deficiency level in certain years for part of the season without showing deficiency symptoms, while in years of heavy crop, prunes with about the same degree of injury varied within a range up to double the upper amount for shoot leaves given in Goodall and Gregory's table.

McCollam (1952) has suggested values of sufficiency for K for the four species considered here as follows: apricot, 2.00 per cent; prune, 1.50 per cent; peach, 1.50 per cent; and pear, 1.00 per cent. Symptoms should be evident at 1.00 per cent, 0.75 per cent, 0.75 per cent, and 0.50 per cent respectively. These values are for leaves near the base of shoots collected between June 15 and July 15. The K contents reported here are well above the sufficiency level indicated for apricot; are in the doubtful range for prune; range from doubtful to deficient for peach; and from adequate to doubtful for pear. The same group of trees may appear in one category in one season and another category in another season; or in one category at the beginning of the sampling period indicated, and in another at the end of it a month later.

The case of the prune merits special attention. Leaf scorch and dieback have been associated with K deficiency (Lilleland, 1932). It would appear that size of crop and the high Mg content of the soil may be of greater importance in producing scorch in this orchard than the K supply even though there is correlation between the K level and the degree of injury.

Phosphorous changes, except for the apricot, follow a more regular pattern than do those of N or K. Data from other sources for other species tend to confirm this rapid initial drop with a leveling off in summer with or without a slight rise in the fall as the "typical" situation. It is interesting that the apricot departs radically from this behavior, as it does with respect to potassium. This soil has been considered below average in phosphate by members of the Plant Nutrition Department at Berkeley. Soil solution levels have been below 1 ppm of PO_4, even in the surface soil, and at 6 to 8 feet have been .01 ppm or less. The leaf P, however, is of the same order of magnitude as that shown by the same varieties in other soils, and no evidence of deficiency has been discovered. It would seem that a low level, constantly maintained, will supply trees with adequate phosphorus.

Initially low values which rise fairly steadily throughout the season seem to be "typical" for calcium and magnesium. Variation due to season or treatment seems to be less than for the other nutrients considered here. The markedly lower levels for the pear than for the other species seem the most noteworthy difference developed in these data.

It should not be inferred from these criticisms that the authors are opposed to the use of leaf analysis as a research tool. Far too much positive accomplishment has been made in this field for such a position to be tenable, and the authors have used it for thirty years with beneficial results. It is believed, however, that local variations in response should receive considerable weight in any interpretation of analytical data and that rigid general standards of adequacy or deficiency have little validity.

These data suggest further that a series of samples of given trees should

prove more useful than a single sample as a basis for comparison. This would be especially true if nutrients appeared to be in or near the doubtful level, where a single atypical sample might be misleading.

SUMMARY AND CONCLUSIONS

Examination of 1,470 graphs of seasonal changes in content of N, K, P, Ca, and Mg in leaves of four species of fruit trees over a three-year period has led to the following conclusions:

1. Nitrogen is high in the spring and decreases thereafter. The season has a greater influence on the shape of the curve and on the general level than does the covercropping treatment, within the limits of the plots reported here. Samples of the same trees at the same time of the year may show variations from year to year of 20 per cent or more. Differences in level occur between species, the pear being lower than the stone fruits in these experiments.

2. Variations in potassium content are greater than in nitrogen. There is some indication of reduction of K in the alfalfa covercrop treatment. Seasonal differences are pronounced. The level is higher in the prunes in the year of light crop than in the two years of heavy crop. Leaf scorch and dieback occurred in both years of heavy crop. In this orchard the size of crop has more effect on the K content of the leaves of prunes than does covercrop treatment. Potassium is usually high in the spring for prunes, peaches, and pears, but low for apricots. The apricot usually has higher maximum values than the other species.

3. Phosphorous curves tend to follow the general shape of nitrogen curves for all fruits except the apricot. This species shows early minima and late maxima to set it off from the others. The higher P level in apricots than in the other species is also noteworthy.

4. The calcium and magnesium contents are less affected by treatment, season, or species than the other elements. All show spring minima and fall maxima. The calcium values in apricot leaves are higher than in the other species, and the magnesium values are lower in the pears.

5. The differences shown here for unfertilized trees illustrate some of the factors to be considered in the use of leaf analyses as tools for diagnosing nutritional status. Time of sampling, variations from year to year, size of crop, and soil-management practice are reflected in these curves. Marked differences in seasonal curves for apricots in contrast to the other species considered here emphasize the usefulness of seasonal curves in contrast to single samples.

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